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**"Observations of the Dynamical Behavior of Flux Tubes and
High Resolution Techniques in Solar Physics"**

Submitted by

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Observations of the Dynamical Behavior of Flux Tubes and High Resolution
Techniques in Solar Physics

Final Technical Report

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My proposed research encompassed two areas of study: development of high resolution imaging techniques for solar physics, and observations of the dynamic behavior of magnetic field lines in the solar photosphere. These areas of research are complementary, since magnetic fields can occur on very small spatial scales.

My proposed research included the development of a wavefront sensor which might be used on extended sources, such as solar granulation. The method is based on curvature sensing - a wavefront sensing technique which has already proven its usefulness for night-time astronomy, using stars as point source reference objects. The method differences two oppositely, but equally defocused images to retrieve the wavefront Laplacian, which can then be solved to yield the wavefront and point spread function. This information can either be used in post-processing to correct the image, or with an adaptive mirror which compensates for the wavefront error in real-time. To adapt this technique for use on extended reference objects, the Fourier transforms of two pairs of extrafocal images, rather than the images themselves, are differenced.

To understand how this might work, consider an optical system containing defocus. Two oppositely defocused images, each the same distance from the true focal plane, will differ in that one will be slightly closer to the actual defocused image plane. The one which is closer to actual focus will contain more high frequency information than the extrafocal image which is farther away. Thus, defocus can be easily measured by comparing the power spectra of the Fourier transformed images. Astigmatic aberrations cause a blurring of the image in one direction. This can be measured as a power spectrum which has higher frequency power along one direction in the frequency plane. Thus, the difference in extrafocal power spectra as a function of spatial frequency provides information on higher order symmetric aberrations.

Likewise, the asymmetric aberrations (tilt, coma, etc) can be measured by looking at the difference in Fourier phase between two oppositely, but equally defocused images. For example, a tilt of the wavefront results in image motion at the focal plane. In the defocused images, this motion will occur in opposite directions. Thus the phase of the Fourier transforms of these images will be shifted from one another, the shift being easily determined when the difference is taken. Again, higher order aberrations can be determined by measuring this shift as a function of spatial frequency. Tilt exhibits a shift which is linear as a function of spatial frequency, while coma shows a decrease of shift at higher spatial frequencies.

The simulations for this work are completed. I have developed normalized signals which return the aberrated wavefront to within 5% rms error. I have established that the signals are linear with respect to aberration amplitude and extrafocal distance,

provided the images are taken well outside the caustic region. I have developed techniques and software for retrieving the static aberrations from telescope systems. I have also investigated the problem of using such a wavefront sensor in real-time to measure aberrations caused by the turbulent atmosphere above the telescope. Work in progress includes lab-tests to reinforce the simulation results.

Preliminary results of this work were presented in the 1994 SPIE Astronomical Instrumentation Conference in Kona, HI, March, 1994, and were published in the proceedings of that conference. This research was also presented at the GSRP Symposium in May, 1994. A paper describing all simulation results is currently in preparation, and will be submitted to a refereed journal by December, 1996.

The second part of my proposed research was an observational study of the dynamical behavior of flux tubes. It is believed that waves travelling along magnetic field lines could be responsible for providing much of the energy needed to heat the solar corona. However, because they would occur on such small spatial scales, these waves have not yet been detected. I proposed to adapt the Mees Observatory 10 inch coronagraph/spectrograph to perform polarimetry, and to equip the instrument with a slit-jaw camera. In this way I hoped to obtain high resolution Stokes I, Q, U and V spectra of the Fe II 6302 lines. Measurement of the line centers and asymmetries of the profiles as a function of time provide information about the dynamics of the magnetic fields. Because I am measuring these profiles in polarized light, the signal will not be contaminated by non-magnetic elements. The simultaneous slit-jaw image provides an absolute spatial reference for each scanned slit position. This information can be used later to register each consecutive image, assuring that the spectral property which has been measured applies to the same magnetic field element.

This work required a significant amount of instrumentation changes to the MCCD. The implementation of a polarization analysis package for the MCCD was completed in September, 1994. This package includes two variable liquid crystal retarders and a Wollaston prism. The variable retarders allow sampling of all Stokes vectors, and the Wollaston provides that orthogonal states of polarization (i.e. +V and -V) can be measured simultaneously.

A second phase of instrumentation work was completed in December, 1995, when the optics for the MCCD image stablizer were upgraded and the optical and mechanical components of the slit-jaw camera were installed. Final implementation of the slit-jaw camera was completed by August, 1996.

Preliminary data was taken on September 26 and 27, 1996. Data was taken on a 21.6 x 40 arcsecond quiet Sun region near disk center, with a cadence of one image cube (including spectral information, and three polarization states) every 23 seconds. Simultaneous slit-jaw images were taken with each of the slit positions and polarization states. Data analysis is currently in progress.

I'm hoping to obtain more data in the upcoming months (hoping for an active region during solar minimum!). My current plan is to finish my dissertation within a year of obtaining data.